Instruction Manual

Model 62A

Inductance Meter

MP MASTER
MA24720

62A
a-1175

BOONTON ELECTRONICS CORPORATION

TEL: 201-887-5110
TWX: 710-986-8241
ROUTE 287 AT SMITH ROAD
PARSIPPANY, N.J. 07054 USA

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CHAPTER I

INTRODUCTION

1.1 GENERAL

The Model 62A Inductance Meter provides instant, direct reading measurements from 0.01 to 3000 μH. This coverage is divided into 8 ranges, selected either by the front panel switch or remotely, arranged in a 1 - 3 - 10 sequence. The solid-state design and crystal-controlled signal source contribute to the high stability and excellent reliability of the instrument.

The 1 MHz test signal current is constant for any given range, as shown in the following table:

1 and 3 μH, fs	160 μA
10 and 30 μH, fs	16 μA
100 and 300 μH, fs	1.6 μA
1 and 3 mH, fs	160 nA

The Model 62A employs a range-switching system using miniature reed relays. The phase-sensitive detection system permits the measurement of even low-Q (series) devices (down to Q = 5) without sensibly degrading the accuracy of the measurement.

A linear dc output is available at rear-panel terminals as well as at the appropriate pins on the edge connector. This feature extends the range of applications beyond ordinary laboratory measurements to include production testing as well as a variety of control functions. Flexibility is further enhanced by the provision of remote ranging terminals; the instrument is fully capable of integration into a controlled test system for rapid, production-line testing.

Remote ranging is controlled by grounding the MANUAL DISABLE terminal on the rear edge connector, disabling the front-panel range switch. Grounding any one of the eight range-line terminals will then select that range.

Connection to the rear panel edge connector should be made with an Amphenol Type 225-22221-101 connector.

CHAPTER II

SPECIFICATIONS

Inductance Range:	0.01 to 3000 µH
Full Scale Ranges:	1, 3, 10, 30, 100, 300, 1000, 3000 µH
Accuracy:	
1 - 300 µH fs	±0.5% rdg ±0.5% fs (Q* > 5)
1000 µH fs	±1.0% rdg ±0.5% fs (Q* > 5)
3000 µH fs	±1.5% rdg ±0.5% fs (Q* > 5)

*Model 62A measures equivalent series inductance. Q's given are the result of series resistance. If loss appears in parallel with the test specimen, the 62A will read the equivalent series inductance, i.e., a 10 µH inductor with a Q of 1.0, owing to parallel loss, will measure 5 µH which is the equivalent series inductance.

Resolution:	0.5% of fs on all ranges
Meter:	4-1/2" taut-band type; two linear scales, 0 to 10 (0.1 per division), and 0 to 30 (0.5 per division)
DC Output:	1 volt fs, adjustable ±2% at 1, 10, 100, 1000 µH 3 volts fs, adjustable ±2% at 3, 30, 300, 3000 µH
Linearity:	±0.25% rdg ±0.02% fs 3000 µH range: ±0.5% rdg ±0.02% fs
Source Resistance:	1 kΩ

Noise < 1mV all ranges

Test Signal: 1 MHz, crystal-controlled

Test Current:

1 and 3 µH, fs	160 µA
10 and 30 µH, fs	16 µA
100 and 300 µH, fs	1.6 µA
1 and 3 mH, fs	160 nA

Temperature Influence:

Temperature Range	Max. Influence
Reference 21°C to 25°C	0
Normal 18°C to 30°C	0.2% of rdg
Extreme 10°C to 40°C	0.5% of rdg

Accessories Available:

62-1A remote test fixture, extends test connectors 30 inches (76 cm)

92-1A single rack-mounting kit (mouts left or right)

92-1B dual rack-mounting kit

Power Requirements: 100, 120, 220, 240 V ac - selectable on rear panel; 50 to 400 Hz; 7 watts

Dimensions: 5.2" high, 8.3" wide, 12" deep (132 x 211 x 305 mm)

CHAPTER III

OPERATION

3.1 INSTALLATION

Each instrument has been inspected and tested at the factory for full compliance with all specifications before packing. Should any indication of shipping damage be apparent upon unpacking, be sure to notify the carrier and the factory immediately. It is recommended that the special packing materials be saved for use in the event that the instrument must be reshipped in the future.

3.1.1 Operating Controls and Indicators

ITEM	FUNCTION
FULL SCALE μH	This switch selects the full-scale range of the instrument; it has 8 positions ranging from 1 μH to 3000 μH full-scale.
PWR Switch	This rocker-type switch turns on the ac primary power. The translucent plastic rocker also serves as the pilot light.
ZERO	This screwdriver adjustment through the front panel is used for setting the low end of the lowest range (1 μH).
METER	A 4-1/2 inch taut-band meter with two linear scales, reading 0 to 10 with 0.1 per division and 0 to 30 with 0.5 per division.

(The following items are on the rear panel.)

ANALOG OUTPUT Terminals — A dc voltage proportional to the meter reading is available at these terminals adjustable ±2%.

FS output: 1 volt (1-series ranges)
3 volts (3-series ranges)

Source resistance: 1 kΩ

LINE VOLTAGE Switch — This switch must be set to the appropriate line voltage - 100, 120, 220 or 240 volts, 50/400 Hz.

Fuse Holder — This contains the main line fuse, which should be either a 0.1 ampere for 220/240 V or a 0.2 ampere for 100/120 V.

P3 — 22-pin edge connector for remote ranging and output connections. (See Figure , page for pin designations.)

This safety requirement symbol has been adopted by the International Electrotechnical Commission, Document 66 (Central Office) 3, paragraph 5.3 which directs that an instrument be so labeled, if, for the correct use of the instrument, it is necessary to refer to the instruction manual. In this case it is recommended that reference be made to the instruction manual when connecting the instrument to the proper power source.

3.2 OPERATION

3.2.1 See that the rear-panel voltage selector switch is in the proper position for the line voltage used. Adjust (if necessary) the mechanical zero screw of the meter, plug the instrument into a power outlet, and allow it to warm up for a few minutes.

3.2.2 Connect a 0.75 inch (1.9 cm) piece of Number 2 AWG wire directly across the test terminals. Check the 1 μH range for an indication of 0.01 μH (1 minor meter division). Adjust the zero control if required. All other ranges should read zero. If not, refer to the maintenance and troubleshooting section of this manual.

3.2.3 The instrument is now ready for use. Connect the test specimen to the terminals and set the range switch to the appropriate range to obtain a maximum upscale reading.

CHAPTER IV

APPLICATIONS

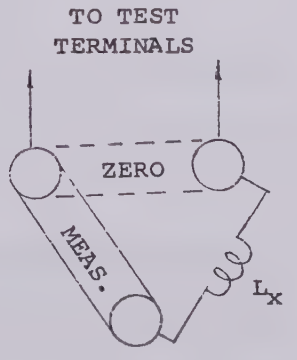
4.1 INTRODUCTION

This information can be used to extend the usefulness and improve the accuracy of measurements when using the Boonton Model 62 Series of Inductance Meters.

4.2 MEASURING LOW VALUES OF INDUCTANCE

When measuring low values of inductance, zero adjustments must be carefully checked. Because all shorting straps have finite inductance, and usually it is an unknown value, we recommend the use of a straight length of #22 solid wire connected between the front panel binding posts. The effective length is in the order of 13 mm with an inductance of approximately 0.0075 μH. The same size wire clamped under the closely spaced posts of the Model 62-1A Test Fixture of the Model 62 Inductance Meters will have an effective length of 11.5 mm, and an inductance of about 0.0065 μH. With such a shorting wire in either place the appropriate adjustments should be made to yield a reading as near to the calculated value as possible.

If many measurements are to be made of low values of inductance it may be desirable to construct a simple fixture with three equally spaced terminals on an insulated board, as shown. When the shorting link is in the dotted position the instrument should be adjusted for a reading of zero inductance. The link is then swung to the solid line position and the test specimen is connected as shown. Because the link is in the circuit for both zero and measurement conditions, its value is sensibly zero,



although owing to minor effects of mutual inductance its presence is not cancelled.

4.3 EFFECT OF DISTRIBUTED CAPACITANCE

The distributed, or self-capacitance of an inductor acts to make the apparent inductance higher than its actual value. The relationship is:

$$L_a = L/(1 - \omega^2 L C_d)$$

Where L_a = apparent inductance
L = actual inductance
C_d = distributed capacitance

Any additional capacitance that is placed across the inductor because of binding posts, connecting leads, proximity to high dielectric material, etc., will further increase the apparent inductance of the test specimen. It is interesting to note that the term $\omega^2 L C_d$ is the ratio of X_L/X_{C_d} and the term becomes more significant as X_L increases with larger values of inductance.

4.4 MUTUAL INDUCTANCE

When two coils are so arranged that the flux produced by current flowing through the first coil links the second coil, the two coils are considered to be coupled by a mutual inductance. The polarity may be either negative or positive depending on the direction of the magnetomotive force produced in each coil by an assumed current flow. It is positive if the forces oppose and negative if they add. The direction of the force in each coil may be found with the well known left hand rule. The polarities of the mutual inductances for several winding directions and coil positions are shown in Figure 1.

The polarity may also be determined by measuring the inductance of the coils individually and the total inductance of the two coils in series. If the total series inductance is greater than the sum of the individual inductances, the mutual inductance is negative. It is positive if the series inductance is less than the sum of the separate coils.

4.4.1 Coefficient of Coupling

The coefficient of inductive coupling is a measure of the extent of completeness with which the flux of one coil embraces the other. It is usually represented by k and is defined as the ratio of mutual impedance to the square root of the product of the total impedances of the same kind as the coupling impedance that are present in the two circuits. Thus, in Figure 2,

$$k = Z_m / \sqrt{Z_1 Z_2}$$

where $Z_1 = Z_1' + Z_m$

$Z_2 = Z_2' + Z_m$

4.5 SERIES AND PARALLEL COILS

The influence of inductive coupling on coils which are connected in either series or parallel is worth considering before proceeding to the discussion of transformers. When the two coils of Figure 3, for example, are series connected by joining terminals 2 and 3, the magnetomotive forces of both coils combine and the inductance between terminals 1 and 4 is greater than the sum of the inductances of the two coils alone. An equivalent circuit of this arrangement is drawn in Figure 4a. The total inductance between 1 and 4 can be seen to be the sum of L_1, L_2, and 2M. Or,

$$L_{ser\ aid} = L_1 + L_2 + 2M$$

It should be noted that any connection to the junction of terminals 2 and 3 is made in series with the negative mutual inductance, -M, and not to point 5 which is unavailable.

Should we reverse the winding direction of either L_1 or L_2, or reconnect the two coils by joining terminals 2 and 4 (or 1 and 3), the equivalent circuit is then represented by Figure 4b. The magnetic forces are opposed and the mutual inductance is positive. It follows from Figure 4b that the total inductance between terminals 1 and 3 is

$$L_{ser\ opp} = L_1 + L_2 - 2M$$

The mutual inductance is one-fourth the difference between the total inductance measured with the series aiding and series opposing connections.

$$M = (L_{sa} - L_{so})/4$$

Paralleling the two coils of Figure 3 by connecting terminals 1 to 3 and 2 to 4 results in the equivalent circuit of Figure 5a. When coils are parallel connected and the magnetomotive forces add, the mutual inductance is positive. The total inductance between terminal 1-3 and 2-4 can be shown to equal

$$L_{par\ aid} = \frac{L_1L_2 - M^2}{L_1 + L_2 - 2M}$$

For coils connected in parallel aiding the limit of the total inductance as k approaches unity is $\sqrt{L_1L_2}$.

It is apparent when the connection of one coil (or the direction of one winding) is reversed, the fields oppose and the mutual inductance is negative. The equivalent circuit is that of Figure 5b and the total inductance is

$$L_{par\ opp} = \frac{L_1L_2 - M^2}{L_1 + L_2 + 2M}$$

It is interesting to note that as $k \rightarrow 1.0$, $M^2 \rightarrow L_1L_2$. Thus, the total inductance approaches zero.

4.5.1 Bridged-Tee Coils

A coil for symmetrical bridged-tee filter network applications must be tapped at its electrical center and the mutual inductance adjusted (by proper selection of winding pitch, wire size, form factor, etc.) to fall within a

few percent of the calculated design value. The total inductance of such a coil is composed of the two halves of the coil connected in series aiding. If, however, the extremities of the coil are joined to form one terminal and the center tap is used for the other terminal, the two halves of the coil are then connected parallel opposing. This arrangement is shown in Figure 6.

These connections are useful for the measurement of the coefficient of coupling and mutual inductance between windings, particularly when the coupling is not tight (between about 0.05 and 0.25).

Using the values of measured inductance for the series aiding connection (L_{sa}), and the parallel opposing connection (L_{po}),

$$M^2 = \frac{L_{sa}L_{po}}{1/k^2 - 1}$$

and

$$k^2 = \frac{1}{L_{sa}L_{po}/M^2 + 1}$$

When the design of a bridged-tee filter is complete, the inductance of each half of the coil, L_1, and the mutual inductance, M, will be known. The problem then is to construct and adjust the coupling between halves of the coil to satisfy the design parameters. Obviously, the best design is one in which the winding pitch is constant and a function of wire size, with values L_1 and M simultaneously satisfied.

Thus, for convenience of adjustment, it is best to arrange an expression which relates the product of L_{sa} and L_{po} to these design factors.

$$L_{sa}L_{po} = L_1^2 - M^2$$

Also,

$$L_1 = L_{sa}/4 + L_{po}$$

and

$$M = L_{sa}/4 - L_{po}$$

4.6 TRANSFORMERS

When two coils form the windings of a transformer and the polarity of the mutual inductance must be determined, the two low potential ends of the coils should be joined and the direction of the magnetomotive forces established by assuming a current flow through both coils. If the coupling is reasonably tight the polarity and the magnitude of M can be measured as described earlier for series coils.

A more direct measurement of the coefficient of coupling of moderate to tight coupled coils has been well documented in the literature. It can be readily shown that when a measurement of inductance is made on one winding, first with the other winding open-circuited (L_o), and then with that winding short-circuited (L_s), the coupling coefficient is,

$$k = \sqrt{1 - L_s/L_o}$$

4.6.1 Link Coupling

Figure 7 illustrates a typical link coupled system. Using k as previously defined, we may write

$$k_1 = M_1/\sqrt{L_p L_m}$$

and

$$k_2 = M_2/\sqrt{L_s L_m}$$

where $L_m = L_1 + L_2$

It can be shown that,

$$k = \frac{M_1 M_2}{\sqrt{(L_p L_m - M_1^2)(L_s L_m - M_2^2)}} = \frac{k_1 k_2}{\sqrt{(1 - k_1^2)\ (1 - k_2^2)}}$$

When k_1 and k_2 are small (less than about 0.2), the overall coefficient of coupling is very nearly,

$$k \approx k_1 k_2$$

For the special case were $M_1 = M_2$ and $L_p = L_s$,

$$k = k_1^2/(1 - k_1^2)$$

The overall coefficient of link coupling can also be measured using the technique previously described for a transformer. In this case the link remains closed while the primary is measured, first with the output winding, L_s, open-circuited, then with it short-circuited. The calculation is the same as for the transformer.

4.6.2 The Shorting Strap

When using the open-circuit/short-circuit technique to measure k, the inductance of the shorting strap should be as low as possible, especially if the winding being shorted has a low value of inductance. If any appreciable inductance exists in the shorted secondary circuit that does not contribute to the coupling, the measured value of k will be lower than the actual value. If L_{sec} is shorted with a finite inductance, L', the ratio of the measured to the true coefficient of coupling will be,

$$1/\sqrt{1 + L'/L_{sec}}$$

or,

$$k = \sqrt{(1 - L_s/L_o)(1 + L'/L_{sec})}$$

where L_{sec} is measured at the secondary terminals with the primary open-circuited.

4.7 PERMEABILITY OF MAGNETIC MATERIALS

Measurement for permeability, μ', which is the real part of the relative initial permeability is sometimes made by measuring the inductance of a coil wound on a toroidal magnetic sample. The inductance of an equivalent air-core coil is calculated assuming a thin uniform current sheet. The permeability is computed from,

$$\mu' = L_m/L_c$$

where L_m = measured inductance with core
and L_c = calculated inductance

Another technique involves the measured value of L_m and the measured inductance, L_o, of an identical coil wound on an insulated core (i.e., polystyrene) having the same dimensions as the magnetic core. The permeability is computed from,

$$\mu' = L_m/L_o$$

Both of these techniques are tedious and suffer from a lack of accuracy. Danielson and Harrington have suggested* a means of reducing the errors usually associated with the measurement of the permeability of toroidal cores. A study of many measurements showed the errors to be largely independent of the

*"A Technique for Reducing Errors in Permeability Measurements with Coils", B. L. Danielson and R. D. Harrington, Proc. of IRE, Vol. 48, No. 3; March 1960; pp. 365-366.

permeability. The authors experimentally demonstrated that using their technique, good accuracy obtained for measurements of low permeability cores using only a few turns. It was further shown that spacing between the core sample and the wire improved the results. Their analysis was as follows.

If we let ΔL be the error in the measured values of L_m and L_o, and because ΔL is nearly independent of permeability, we can write for the correct values of L_m and L_o:

$$L_m = \mu' L_c + \Delta L$$

and

$$L_o = L_c + \Delta L$$

Subtracting yields an expression for μ' which agrees remarkably well with the experimental measurements.

$$\mu' = \frac{L_m - L_o}{L_c} + 1$$

Danielson and Harrington suggested that a simple demountable coil of a few turns would make a convenient measuring device. Such a fixture has been designed by Boonton Electronics and is designated Model 63-11B Mu Jig. When used with the Model 62 Inductance Meter it permits a simple and accurate means for measuring permeability.

The 63-11B is a molded fixture consisting of 7 turns of wire which can be opened (via connecting pins and receptacles) to accept magnetic cores with the following maximum or minimum restrictions:

	Minimum I.D.	Maximum O.D.
Height up to 0.31 " (7.87 mm)	0.27" (6.86 mm)	1.9" (48.3 mm)
Height up to 0.58" (14.7 mm)	0.50" (12.7 mm)	1.9" (48.3 mm)

The measurement and calculation for μ' can be made by:

1) Measuring the inductance of the Mu Jig without the core. This is L_o.

2) Measuring the inductance of the Mu Jig with the core installed. This is L_m.

3) Calculating the inductance of a 7 turn air-core coil having the dimensions of the sample core. This is L_c.

$$L_c = 0.0117\ (h)N^2\ \log_{10}(d_o/d_i)$$

where N = number of turns (7)
h = height of core (inches)
d_o = outside diameter of core
d_i = inside diameter of core

The permeability is then calculated from the equation given previously.

Example: The empty Mu Jig measures 0.805 μH. With the sample core in place, the measured inductance is 4.13 μH. The core height measures 0.25 inch, the O.D. is 0.875 inch, and the I.D. is 0.55 inch. L_c is calculated to equal 0.0289 μH.

$$\mu' = (4.13 - 0.805)/0.0289 + 1 = 116$$

4.7.1 B-H Curves

Because of the extremely low test current (160 μA, or less) of the 62 Inductance Meter, and the relatively few turns in the 63-11B Mu Jig the magnetizing force should not exceed 0.002 Oersted. This assures a measurement of permeability at the origin of the B-H curve which is known as initial permeability. To study the change of permeability as the magnetizing force is increased, additional turns of thin wire may be wound directly on the core

with the leads brought out between halves of the engaged fixture. Direct current (or ac, if desired) can be passed through these turns as the inductance of the Mu Jig with the sample core is monitored on the 62 Inductance Meter. Because of the probable loading effects of the bias supply across the additional turns on the core, a simple 1 MHz parallel resonant circuit should be placed in series with the bias supply. The immunity offered by the resonant circuit can be easily checked by connecting it across the bias winding while observing the measured inductance which, of course, should not change. If the parallel resonant inductor has a magnetic core it should have an air gap sufficient to prevent its inductance from changing with bias current.

4.7.2 Cylindrical Cores

When cylindrical magnetic cores are used to increase the inductance of solenoids, the magnetic flux exists in both magnetic material and air. The coil functions, therefore, in a medium that has an effective permeability, μ_e, less than the actual permeability of the magnetic material. The effective permeability of a cylindrical core may be defined as the ratio of the inductance of a coil, first with and then without the core. The coil in this instance is assumed to be wound of infinitely thin wire on the surface of the core throughout its entire length.

W. J. Polydoroff* has shown the effective permeability to be related to the permeability as a function of core-length to core-diameter. Polydoroff's curves are reproduced in Figures ~~7 and 8.~~ 9+10 It is interesting to note that unless large ratios of core-length to core-diameter are used, only a small fraction of the permeability is realized as effective permeability. Thus, we can start with a magnetic alloy whose permeability is 23. Then if we assume the ratio of core length to diameter is unity, the effective permeability will be only about 3.9. Moreover, when the core is used with a coil wound

*Polydoroff, W. J. and Klapperich, A. J., "Effective Permeability of High Frequency Iron Cores", Radio, Nov. 1945.

on a form of finite wall thickness, the increase of inductance will be substantially less than 3.9 times that of the coil in air. This last reduction of apparent permeability is due to the difference between core area and mean coil area. In an excellent treatment of the subject, Foster and Newlon* developed an equation that relates the effective permeability and the ratio of core to coil diameters, L_i/L_o,

$$L_i/L_o = 1 + (d_i/d_o)^2(\mu_e - 1)$$

Rearranging,

$$\mu_e = \frac{(L_i/L_o) - 1}{(d_i/d_o)^2} + 1$$

where L_o = inductance of the coil in air
L_i = inductance of the coil with a core (core length = coil length)
d_o = mean diameter of the coil (any units)
d_i = diameter of the core (same units as coil)
and μ_e = effective permeability of the core

If two coils of identical length but different diameters are compared with the same core, the equation can be used to predict with good agreement the change in the L_i/L_o ratio.

In many cases the length of a sample core may differ from the length of the core required for a final design. Similarly the test coil used to measure the core may be longer or shorter than the finished coil. Other equations are obviously needed to compensate for the change in Nagaoka's constant when coils and cores of various lengths are compared.

*Foster, Dudley E., and Newlon, Arthur E., "Measurement of Iron Cores at Radio Frequencies", Proc. I.R.E., vol. 29, May 1941, pp. 266 - 276.

If we let μ_e' be the effective permeability of cores which are longer or shorter than the core used to determine μ_e, three empirical expressions have been developed for the ratio μ_e'/μ_e.

1) When the test coil is used with a longer core,
$\mu_e'/\mu_e = (\text{core length/coil length})^{0.56}$

2) When the test coil is used with a shorter core,
$\mu_e'/\mu_e = (\text{core length/coil length})^{0.88}$

3) When the test coil is used with a longer core,
$\mu_e'/\mu_e = (\text{core length/coil length})^{0.25}$

As an example, assume the following:

Coil Data		Core Data	
Number of turns	35	Material	Pyroferric PY-14A
Wire size	#28 PE	Diameter	0.368"
Mean diameter	0.511"	Length	0.492"
Length	0.492"		

The inductance of the coil alone measures 10.98 μH. With the core inserted the inductance measures 22.3 μH. The ratio of L_i/L_o is 2.03. Using this to find the effective permeability, μ_e,

$$\mu_e = (1.03/0.5186) + 1 = 2.99$$

If this coil is used with a core of the same material and diameter, but a length of 0.984 inch, what inductance should we expect with this longer core?

$$\mu_e' = 2.99(0.984/0.492)^{0.56} = 4.41$$

Using this value,

$$L_i/L_o = 1 + 0.5186(4.41 - 1) = 2.77$$

Since the initial inductance of the coil was 10.98 μH, we can expect the inductance of the coil with the onger core to be 30.4 μH. The actual measured value was 29.8 μH, an error of about 2%.

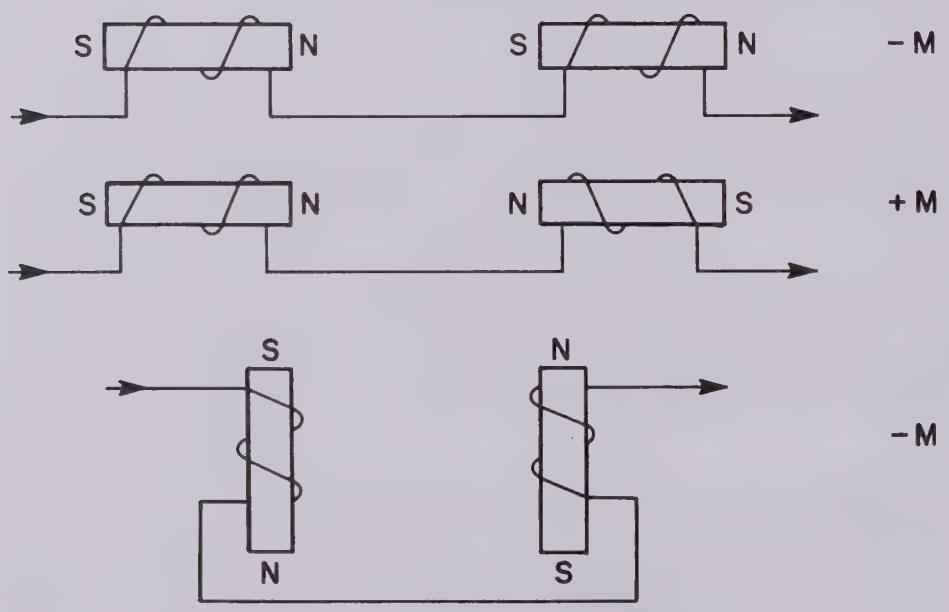


FIG. 1

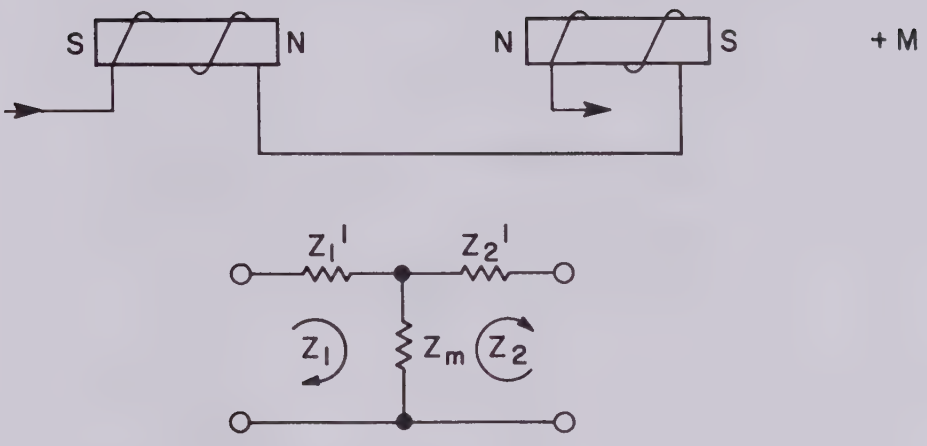


FIG.2

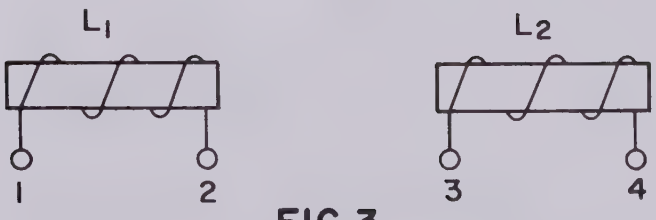


FIG.3

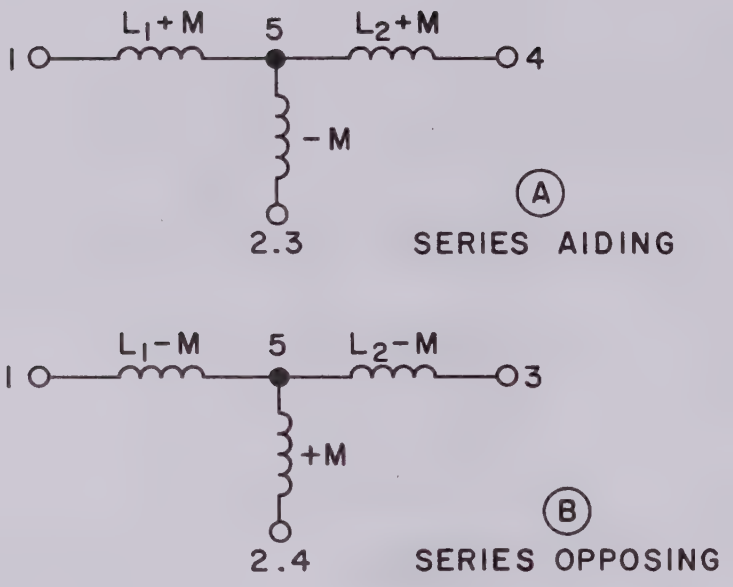

L1+M
5
L2+M
1
4
-M
2.3
A
SERIES AIDING
L1-M
5
L2-M
1
3
+M
2.4
B
SERIES OPPOSING

FIG. 4

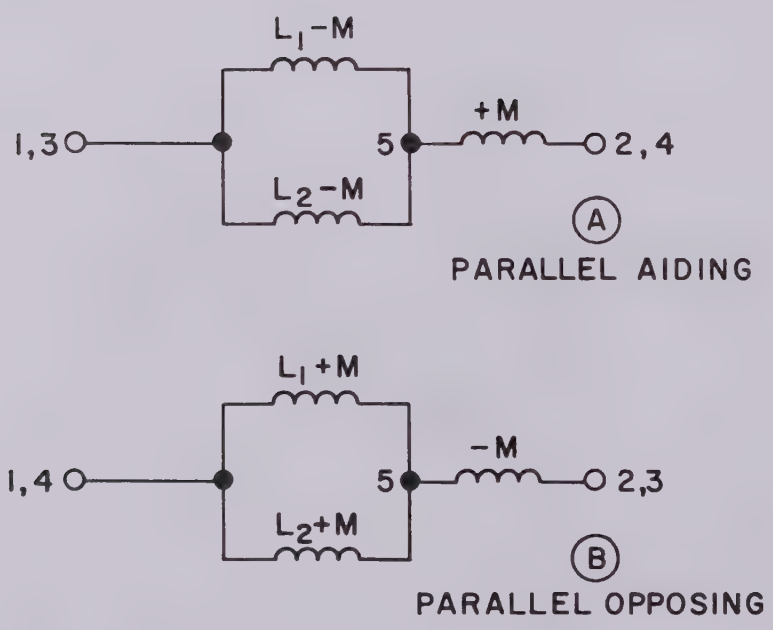

L1-M
1,3
5
+M
2,4
L2-M
A
PARALLEL AIDING
L1+M
1,4
5
-M
2,3
L2+M
B
PARALLEL OPPOSING

FIG. 5

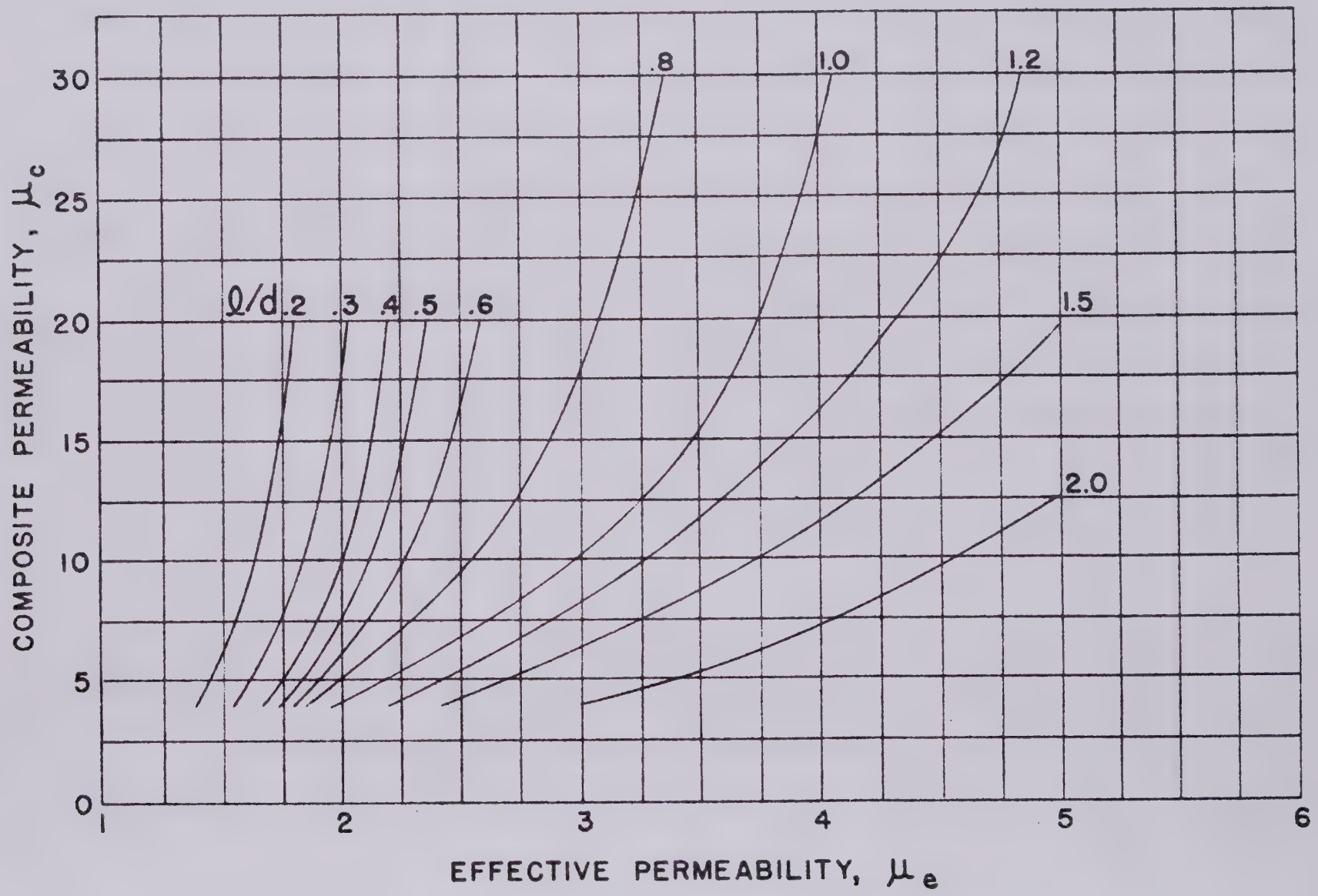

COMPOSITE PERMEABILITY, μ_c
EFFECTIVE PERMEABILITY, μ_e
0
5
10
15
20
25
30
1
2
3
4
5
6
ℓ/d
.2
.3
.4
.5
.6
.8
1.0
1.2
1.5
2.0

Figure 9

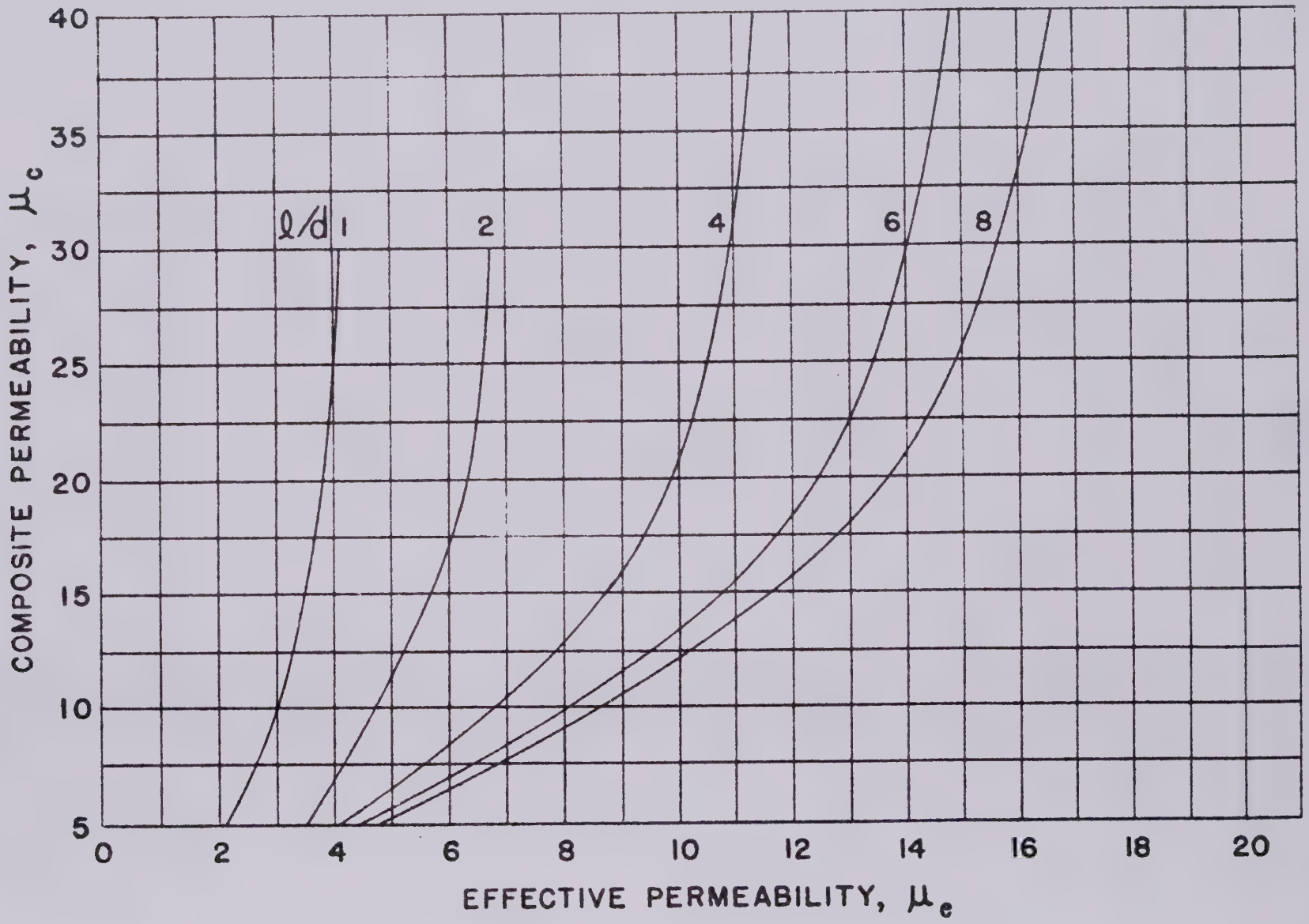

COMPOSITE PERMEABILITY, μ_c
EFFECTIVE PERMEABILITY, μ_e
l/d
1
2
4
6
8
40
35
30
25
20
15
10
5
0
2
4
6
8
10
12
14
16
18
20

Figure 10

FIG. 6

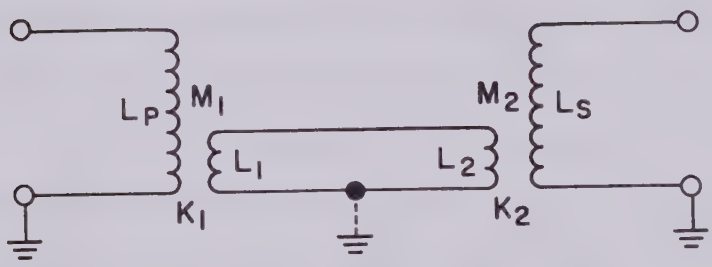


FIG. 7

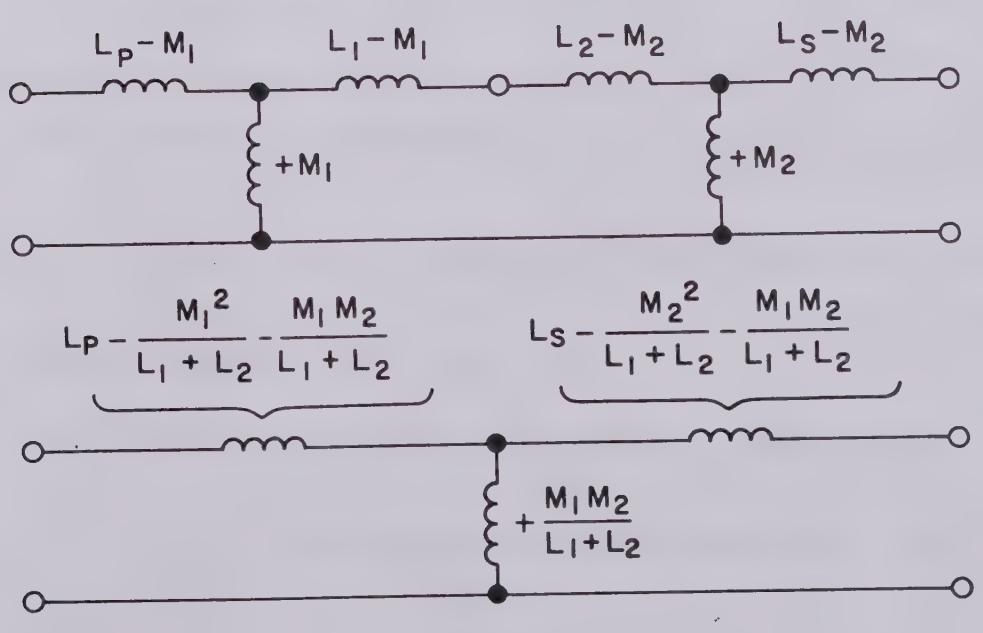


FIG. 8

CHAPTER V

THEORY OF OPERATION

5.1 MEASURING CIRCUITS

When a constant alternating current is passed through an inductor, L_X, the voltage developed across it is proportional to its impedance. If the Q of the inductor is greater than, say 10, the voltage is very nearly proportional to L_X. With a phase sensitive detector to sense the voltage, the quadrature voltage is exactly proportional to L_X.

For the conventional circuits shown in Figures 2 and 3, three sources of error exist: 1) The current is not constant and to some extent depends upon the value of L_X. This is especially true for Figure 3 because the circuit elements are not in quadrature. 2) Capacitance of the test terminals and internal wiring will cause the measured inductance to appear higher than the actual inductance. The condition worsens for larger values of inductance. 3) The phase of the open-circuit voltage is that of the source. An open-circuit terminal condition, therefore, may give a down-scale rather than off-scale reading (depending upon amplifier overload conditions).

A modification of the circuit of Figure 3 overcomes these objections. With an inductor, L, connected across the test terminals, as shown in Figure 4, the ratio of output to generator voltage is

$$e_x/e_g = \frac{\omega L \, \omega L_x}{\omega L X_c + \omega L X_c - \omega L \, \omega L_x}$$

It is evident that if ωL is made equal to X_c, the above expression reduces to

$$e_x/e_g = \omega L_x/X_c = \omega^2 L_x C$$

giving a linear relationship between the output voltage and L_x.

While L and L_X are directly related, and in theory L_X can increase without limit, practically it is better if L_X does not increase beyond some fraction of L. The principal reasons are: 1) the accuracy will suffer unless L is quite stable, 2) its effective value depends upon distributed capacitance and it is not reasonable to expect extreme stability in this parameter, and 3) inductors whose values are greater than about 3 millihenries are subject to a large uncertainty of measurement when measured at 1 MHz. In addition, the Q values of large inductors are generally poor which places a greater burden on the phase detector.

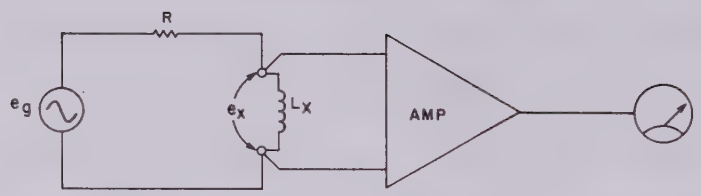
For these reasons the maximum value of L_X for the 62A is held to 3 mH.

As to the problem of the distributed capacitance, the value of L is chosen so that all the circuit capacitance modifies this inductor and brings it up to the correct value. In fact, an additional variable capacitor is included to make this adjustment.

If ωL is made exactly equal to X_C, the open-circuited condition at the test terminals will establish an internal series resonant condition, and the phase of the output voltage will not be proper for an off-scale meter indication. Fortunately, the circuit does not demand exact resonance for excellent linearity. L may be more or less than the ideal value with only a minor effect on the linearity of the output voltage. With the circuit parameters (except for the highest range) used the linearity error is 1/100 the error in the ideal value of L. For example, if L is 2% less than the value required for resonance with C, the output voltage at full-scale will be 0.02% less than ideal.

This permits L to be adjusted somewhat low, making the overall circuit capacitive and for an open-circuited condition the output voltage has the proper phase for an off-scale indication.

With proper amplification and phase detection, the rectified signal is applied to either a 4-1/2 inch taut-band meter or a 4 digit digital panel meter.

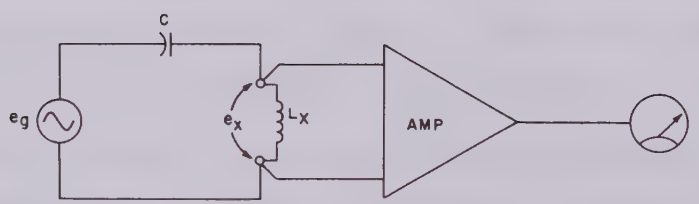


$R >> \omega L_x$

$e_x/e_g = +j\omega L_x/(R + j\omega L_x)$

$R/\omega L_x$	% ERROR AT FS
5	1.942
10	0.496
20	0.125
50	0.020

Figure 2.

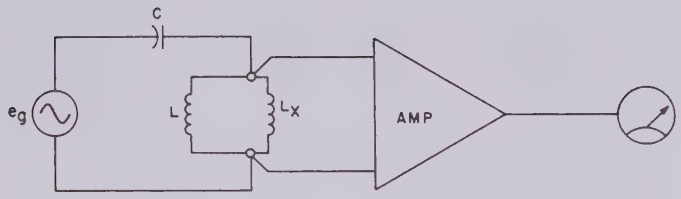


$X_c >> \omega L_x$

$e_x/e_g = \omega L_x/(X_c - \omega L_x)$

$X_c/\omega L_x$	% ERROR AT FS
20	5.26
50	2.04
100	1.01
200	0.50

Figure 3.



$$X_C \quad \omega L >> \omega L_x$$

$$e_x/e_g = \omega L_x/X_c = \omega^2 C L_x$$

e_x is directly proportional to L_x.

Figure 4.

5.2 RANGING CIRCUITS

Range switching in the 62A is accomplished by a combination of the panel range switch and miniature reed relays. The panel switch handles only control voltages; no signal currents pass through its contacts, which eliminates a frequent source of errors and improves reliability.

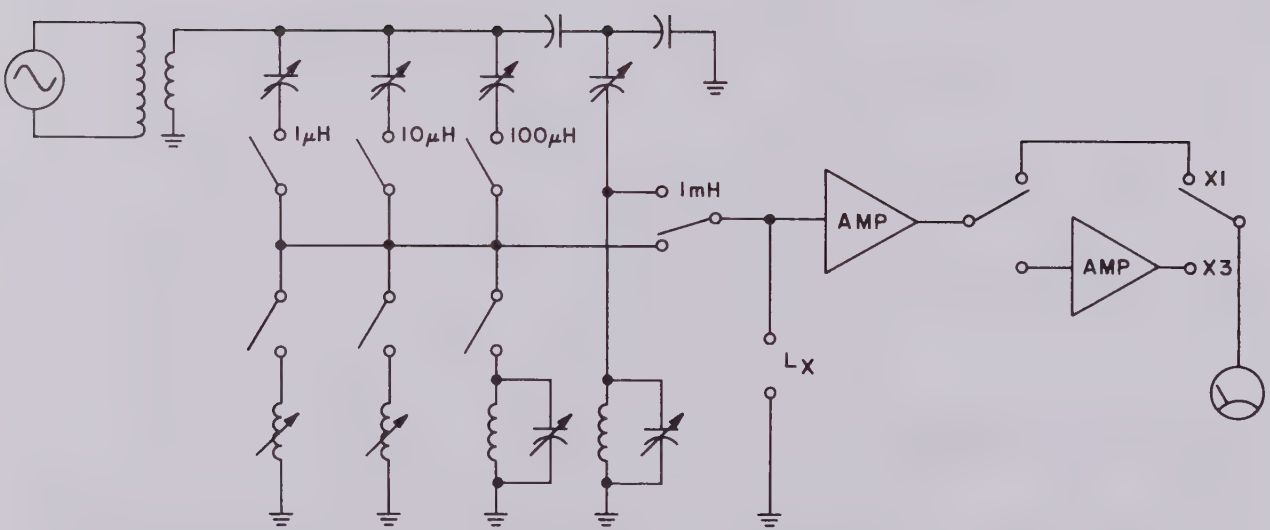


Figure 5. Simplified Schematic of Measuring Circuits

CHAPTER VI

MAINTENANCE

NOTE: Values and tolerances shown in this section are not specifications but are provided only as guides to the maintenance and calibration of this instrument.

6.1 INTRODUCTION

The Model 62A is designed to operate within the stated specifications over a long period. However, to achieve the maximum performance it is desirable to check and adjust the instrument periodically. Basically, two adjustments are recommended:

a. A zero balance check and adjustment every 500 hours of operation (three months of normal use), and
b. A calibration check every 1000 hours of operation (six months of normal use).

In addition to these two periodic checks, complete adjustment procedures are described in paragraphs 6.4 to 6.9. It is felt, however, that after the complete calibration procedures performed at the factory, these adjustments are not needed when the instrument is used in normal laboratory or factory environment. It is recommended they be performed only in case of accidental misadjustment, component failure and replacement, or when the instrument has been subjected to severe environmental stresses, such as shock or vibration.

Complete schematics, parts lists and control and component location drawings are at the end of this manual and should be referred to when servicing is performed. Inside the top cover a brief description of adjustments and their locations is given.

For all calibration checks a minimum one hour warmup is suggested.

6.2 REQUIRED TEST EQUIPMENT

6.2.1 Digital or differential dc voltmeter, 0.001 - 100 V; ±0.05% accuracy (Fluke Model 8100 or equivalent).

6.2.2 DC VOM, 1 MΩ input resistance.

6.2.3 RF Millivoltmeter, Boonton Electronics Model 93A.

6.2.4 Inductance standards of 1, 3, 10, 30, 100, 300, 1000 and 3000 μH at 1 mHz, accuracy of better than ±0.5%.

6.3 VISUAL INSPECTION

IF the instrument fails to operate, a visual check should be made first.

6.3.1 Check the fuse in the rear panel. Proper sizes for the appropriate line voltage are indicated on the rear panel.

6.3.2 Check the setting of the rear panel line voltage selection switch.

6.3.3 An internal visual check should be made for loose connectors or leads as well as plug in boards not being seated in their connectors.

6.4 POWER SUPPLY CHECK.

Measure the dc voltage across C21 on the master board. This voltage should be +15 volts ±0.25 volts.

Measure the dc voltage across C22 on the master board. This voltage should be -15 volts ±0.25 volts.

These voltages are adjustable by R9 and R12 respectively and should be adjusted as required.

The dc voltage for the switching circuits at the junction of R14 and CR11 should be a nominal 4.7 volts and not less than 4 volts.

6.5 OSCILLATOR CHECK

The normal meter indication, with an open circuit at the test terminals, is an over full scale reading. An inoperative oscillator circuit would be indicated as a zero meter reading.

The oscillator circuit may be checked by connecting a high impedance dc voltmeter to test point TP1. This voltage should be a nominal 7.5 to 12.5 volts dc. C202 adjusts this voltage to a maximum which should be within the above limits. R202 adjusts the test level but should not be adjusted unless it has been determined that all ranges have the same amount of error of calibration.

6.6 1 MHz AMPLIFIER CHECK

A defective amplifier circuit may give the same indication as a defective oscillator circuit - that is, no off scale indication with the test terminals open. L201 tunes the amplifier to 1 MHz and can only be checked by opening the feedback jumper near L201 and adjusting it for a maximum amplifier output. This adjustment should normally be done with a separate test fixture and a variable frequency and level source. It is not recommended that this adjustment be changed unless L201 is replaced. Other causes of an inoperative amplifier circuit could be defective transistors.

6.7 ZERO ADJUSTMENT

The zero adjustment on the lowest range should be made first by connecting a 0.75 inch (1.9 mm) piece of AWG 22 wire directly across the test terminals. This piece of wire will have an inductance of 0.01 μH. The front panel zero adjustment can be used to set this for 0.01 μH on the lowest range. Switching up to all other ranges, the meter should indicate zero. If it does not, check the meter mechanical zero with the instrument off. Correct its indication as required. If the up range zero is not correct, remove the top cover and adjust R242 for zero indication on the 1 mH range. Return to the lowest range and readjust the front panel zero control as required.

6.8 CALIBRATION ADJUSTMENTS

Using adequate inductance standards, check the full scale indication on the 100 μH range. R37, which is accessible through a slot in the rear panel, will set this indication to the proper full scale indication. Switch to the 300 μH range, and using a 300 μH inductor, adjust R41, also through the rear panel, for the correct indication for this inductor.

The other ranges can be checked as follows:

1000 μH range - Adjust C4 on the left side of the instrument;
10 μH range - Adjust C11 on the left side of the instrument;
1 μH range - Adjust C16 on the left side of the instrument.

As noted in 6.5 above, R202 in the oscillator circuit will change the test level and change the calibration of all ranges by the same amount.

If further adjustment is required for the 100 μH range, C9 will set this range. However, the calibration of the 100 μH range should not be changed by C9 without rechecking the 300 μH range calibration.

6.9 ANALOG OUTPUT ADJUSTMENT

The analog output available at the rear panel terminals or at Pin 4 on P3, the rear edge connector, should correspond to the panel analog meter. The output level may be varied over a limited range of approximately ±2% by control R38 available through the slot in the rear panel. The analog output zero should also agree with the front panel indicator. If it does not, remove the top cover and short test point TP2 with a short lead to an adjacent ground. Set the range switch to the 1 mH position and adjust R27 through the rear panel for a zero indication. The full scale indication should then be rechecked on this range and R38 adjusted as required. The nominal output impedance is 1 kΩ and should be observed when making an external connection to these terminals.

CHAPTER VII

TROUBLESHOOTING PROCEDURE

In case of instrument failure the defective section should be identified and then repaired. The following sections cover in sequence each section that may be defective and information necessary to detect the fault.

7.1 IF INSTRUMENT FAILS TO OPERATE

The rocker on/off switch should be lit when the instrument is turned on. The analog meter should read off scale on all ranges with open circuit test terminals.

If the on/off indicator fails to light or is dim, check the rear panel fuse and the line voltage switch for proper settings.

7.2 POWER SUPPLY SECTION

If the meter does not read off scale proceed to the power supply section. Remove the top cover and note the diagram inside for location of test points.

The normal voltages are:
+15 volts ±0.25 V across capacitor C21. This voltage is set by R9.
-15 volts ±0.25 V across C22. This voltage is set by R12.
+4.7 volts at the junction of CR11 and R14. This is not shown on the diagram but is located in the main board, forward of the plug in board.

A high temperature at the heat sink for regulators IC1 and IC2 indicates a short circuit somewhere in the supply lines. Normal heat sink operation is only warm.

7.3 1 MHz OSCILLATOR

A defective oscillator circuit may be indicated by a lack of an off scale reading with open circuit test terminals or large errors in inductance readings.

The normal dc level at test point TP1 on the plug in board should be +7.5 to 12 volts dc as measured with a high impedance meter. This level can be adjusted for a maximum indication by the adjustment of C202.

The nominal ac level at pin X of this plug in board should be 3.4 V rms, 1 MHz.

The nominal test level at the high test terminal will be 1 mV with a 1 μH inductor connected on the 1 μH range.

If C202 will not tune through a maximum indication of the dc level at TP1, an adjustment of the core of T2 may be required. This would not be a normal requirement but if it should be required, it will first be necessary to remove the nylon locking nut or to use a few drops of lacquer thinner to soften the locking compound of this adjustment. This adjustment would then be made for a maximum dc level at TP1 with C202 set to the center of its range.

If all the above checks do not correct the oscillator defect, a check should be made of transistor Q202. This transistor may be either a 2N5459 or preferably a 2N5949. Several 2N5459 transistors may have to be tried to obtain satisfactory oscillator operation.

7.4 1 MHz AMPLIFIER

The 1 MHz amplifier is a tuned feedback amplifier with a closed loop gain of approximately 54 dB. The open loop gain by stages are:

Q203 and Q204: 54 dB
Q205: 23 dB
Q207: 23 dB

The amplifier is tuned to 1 MHz by L201 when the feedback circuit is opened at the terminals near L201. This is an adjustment not normally required unless L201 is replaced. Defective transistor would usually be the cause of defective amplifier operation.

7.5 PHASE SENSITIVE DETECTOR

The phase sensitive detector consists of diodes CR205 to CR208 and resistors R238, R239, R241 and R243 in a bridge circuit. R242 adjusts the output to zero as noted in 6.7. Normal levels in this circuit are as follows. With a 100 μH test inductor on the 100 μH range, the 1 MHz level at TP3 will be 500 mV. The dc output of the detector at TP2 will be +0.5 volt. The phase reference 1 MHz drive voltage at C228 will be 10 volts. The input to the base of Q206 will be 4.8 volts, 1 MHz.

This circuit is adjusted with a short circuit on the test terminals and the range switch set to the 1 mH range; R242 should be adjusted for a zero dc voltage condition at TP2. With this same condition, C233 should be adjusted for a minimum 1 MHz voltage at TP3. This is typically 35 mV.

Transformer T201 is tuned for a maximum dc voltage output at TP2 with a high Q test inductor such as a 100 μH on the 100 μH range. This adjustment is not normally required except when circuit components are replaced. A fine adjustment of this circuit can be made with C228 and should be set with a standard of 100 μH with a high Q and also one with a Q of approximately 5. C228 should be adjusted for the same dc output under both conditions. Misadjustment of C228 will normally have no affect on measurements of inductors with Q's in excess of 10.

7.6 OUTPUT DC AMPLIFIER

The operational amplifier A1 drives the meter circuit and provides the analog output. Normal levels with a 100 μH test inductor on the 100 μH range should be +0.5 volt input at pin 3 and +3.7 volts at pin 6. A voltage divider with R38 providing approximately a 2% range of adjustment provides an analog output of one volt under this condition. The output impedance at the analog terminals is 1 kΩ.

7.7 MEASURING CIRCUITRY

The 1 MHz oscillator test voltage is coupled off transformer T2 and applied to the measuring circuit through filter L6 and C20. This circuit normally requires no adjustment. In the event of parts replacement L6 should be adjusted for a maximum 1 MHz signal across R7. This normal level should be 100 mV ±10%.

The inductors L2, L3, L4 and L5 will normally require no adjustment. However, if circuit components are replaced they may be readjusted as follows.

Connect an oscilloscope probe to R210 on the oscillator/amplifier plug in board. Set the range switch to the 1 μH range and adjust L5 for a maximum signal on the oscilloscope. The instrument test terminals should be open circuited.

Set the range switch to the 10 μH range and adjust L4 for a maximum signal condition.

Move the oscilloscope probe to R223 and set the range switch to the 1 mH range and adjust C7 for a maximum signal condition.

The procedure for full scale calibration is given in 6.8, Calibration Adjustments.

It may be necessary to recheck several standards on the highest range (1 mH) if C7 has been adjusted. This adjustment will affect the linearity of calibration on this range.

The inductor L1 at the high terminal of the input circuit has a range of inductance to normally zero the instrument on the lowest range. If this inductor is replaced it may be necessary to vary the turns spacing to obtain a zero condition. After this adjustment the turns should be cemented in place.

62A EXTERNAL PROGRAMMING PIN ASSIGNMENTS

TERMINAL	FUNCTION	REMARKS
A	+15 V	Power for BEC supplied options only
B	+5 V	Power for BEC supplied options only
3	GND	
4	+ ANALOG OUTPUT	+1 V fs 1-10-100-1000 range +3 V fs 3-30-300-3000 range Z = 1 kΩ
5	GND	
7	MANUAL DISABLE	Connect to GND to disable front panel programming.
9	3000 µH RANGE	External range programming inputs.
10	1000 µH RANGE	Logic 0 or connection to common
11	300 µH RANGE	selects corresponding range. These
12	100 µH RANGE	lines may be used as outputs to
13	30 µH RANGE	indicate current operating range;
14	10 µH RANGE	the range line corresponding to
15	3 µH RANGE	the operating range will be at
16	1 µH RANGE	logic 0. (logic 0 < +0.5 V)

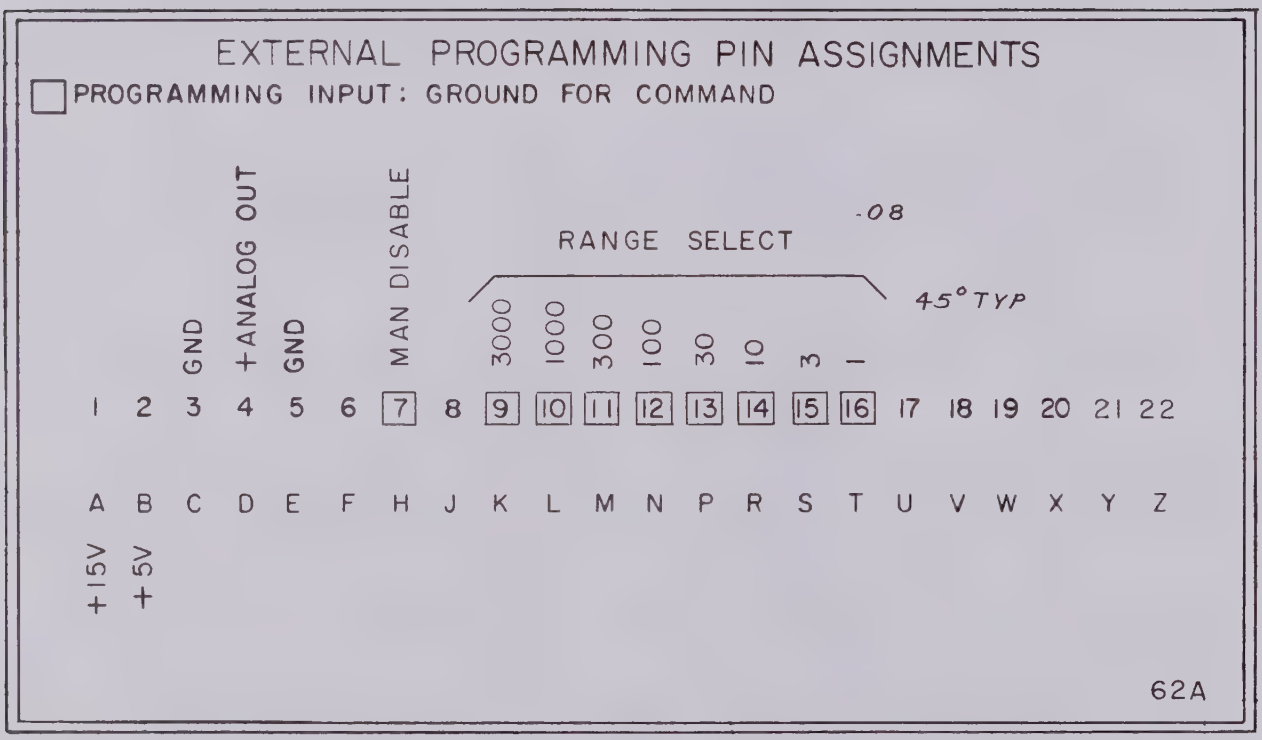


Figure 6. External Connections

TABLE OF REPLACEABLE PARTS

Reference		Description	BEC Part No.
		REAR PANEL, SUB PANEL	
C1	Capacitor, Cer.	0.01 µF 20% 1000 V	224228
C6	Capacitor, Cer.	0.01 µF 20% 1000 V	224228
F1	Fuse	0.2 A 120 V	545508
F1	Fuse	0.1 A 240 V	545519
L1	Coil	M/F 802126	400289
M1	Meter	Analog Movement, M/F 554137, 554248	554318
P1	Connector, Line Cord		477281
S1	Switch		466230
S2, DS1	Switch	On/Off & Pilot Light	465165
S3	Switch	Rotary	466214
S4	Switch	Pushbutton	465164
T1	Transformer, Power		446071
		MASTER PC BOARD	
A1	Op. Amp.	LM301AN	535012
C2	Capacitor, Mica	100 pF 5% 500 V	200001
C3	Capacitor, Mica	910 pF 1% 100 V	200075
C4	Capacitor, Var.	0.35 - 3.5 pF 250 V	279128
C5	Capacitor, PE	0.1 µF 10% 100 V	234080
C7	Capacitor, Var.	1 - 14 pF 250 V	279127
C8	Capacitor, Var.	1 - 14 pF 250 V	279127
C9	Capacitor, Var.	0.35 - 3.5 pF 250 V	279128
C10	Capacitor, Mica	22 pF 5% 500 V	200060
C11	Capacitor, Var.	1.7 - 6 pF 250 V (Red)	281015
C12	Capacitor, Elec.	250 µF 40 V	283207
C13	Capacitor, Elec.	250 µF 40 V	283207
C14		Not Used	
C15	Capacitor, Mica	240 pF 5% 500 V	200106
C16	Capacitor, Var.	2.3 - 20 pF 250 V (Blue)	281005
C17	Capacitor, PE	0.1 µF 10% 100 V	234080
C18	Capacitor, PE	0.1 µF 10% 100 V	234080
C19		Not Used	
C20	Capacitor, Mica	1200 pF 5% 100 V	200105
C21	Capacitor, Elec.	100 µF -10 +75% 25 V	283105
C22	Capacitor, Elec.	100 µF -10 +75% 25 V	283105
C23	Capacitor, Mica	560 pF 1% 300 V	200091
C24	Capacitor, Mica	30 pF 5% 500 V	200073
C25	Capacitor, PE	0.1 µF 10% 100 V	234080

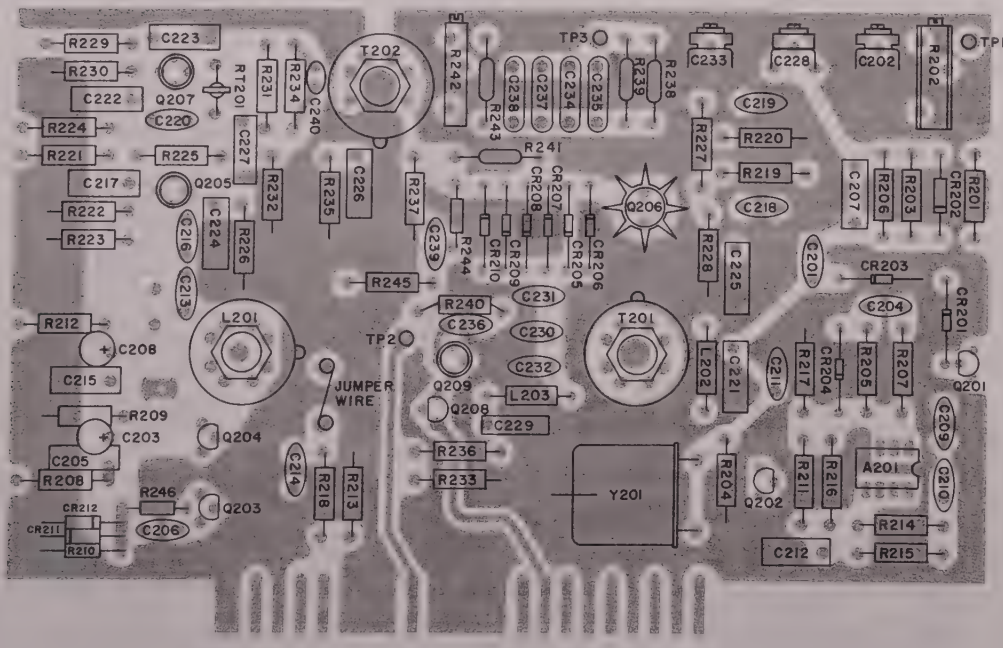
Reference	Description		BEC Part No.
	MASTER PC BOARD (CONTINUED)		
C26	Capacitor, PE	0.022 µF 20% 250 V	234079
CR1	Diode, Sig.	1N914	530058
CR2	Diode, Sig.	1N914	530058
CR3	Diode, Sig.	1N914	530058
CR4	Diode, Br.	KBP-02	532013
CR5	Diode, Br.	KBP-02	532013
CR6		Not Used	
CR7 through CR10	Diode, Sig.	1N914	530058
CR11	Diode, Zen.	1N5230B	530103
CR12	Diode, Sig.	1N914	530058
CR13	Diode, Sig.	1N914	530058
CR14		Not Used	
IC1	I.C.	µA 7805	535011
IC2	I.C.	µA 7805	535011
IC3		Not Used	
IC4	I.C.	MFC 6030	535007
IC5	I.C.	MFC 6030	535007
IC6	I.C.	SN75451AP	534006
IC7	I.C.	SN75451AP	534006
IC8	I.C.	SN75451AP	534006
IC9	I.C.	N8471A	534005
IC10		Not Used	
J2	Connector	22 Pin	479231
K1 through K8	Relay Coil	M/F 802151	470502
L2	Inductor Unit		400286
L3	Inductor Unit		400288
L4	Coil	560 µH	400290
L5	Coil	100 µH	400284
L6	Coil	14 - 28 µH	400231
L7	Choke	2.2 mH	400141
Q1	Transistor	SE 3005	528065
Q2	Transistor	TIS58	528038
R1	Resistor, Comp.	330 Ω 5% 1/4 W	300070
R2	Resistor, Comp.	68 Ω 5% 1/4 W	300054
R3	Resistor, Comp.	68 Ω 5% 1/4 W	300054
R4	Resistor, Comp.	3.3 kΩ 5% 1/4 W	300094
R5	Resistor, Comp.	1 kΩ 5% 1/2 W	301087
R6	Resistor, Comp.	1 kΩ 5% 1/2 W	301087
R7	Resistor, Comp.	10 Ω 5% 1/4 W	300034

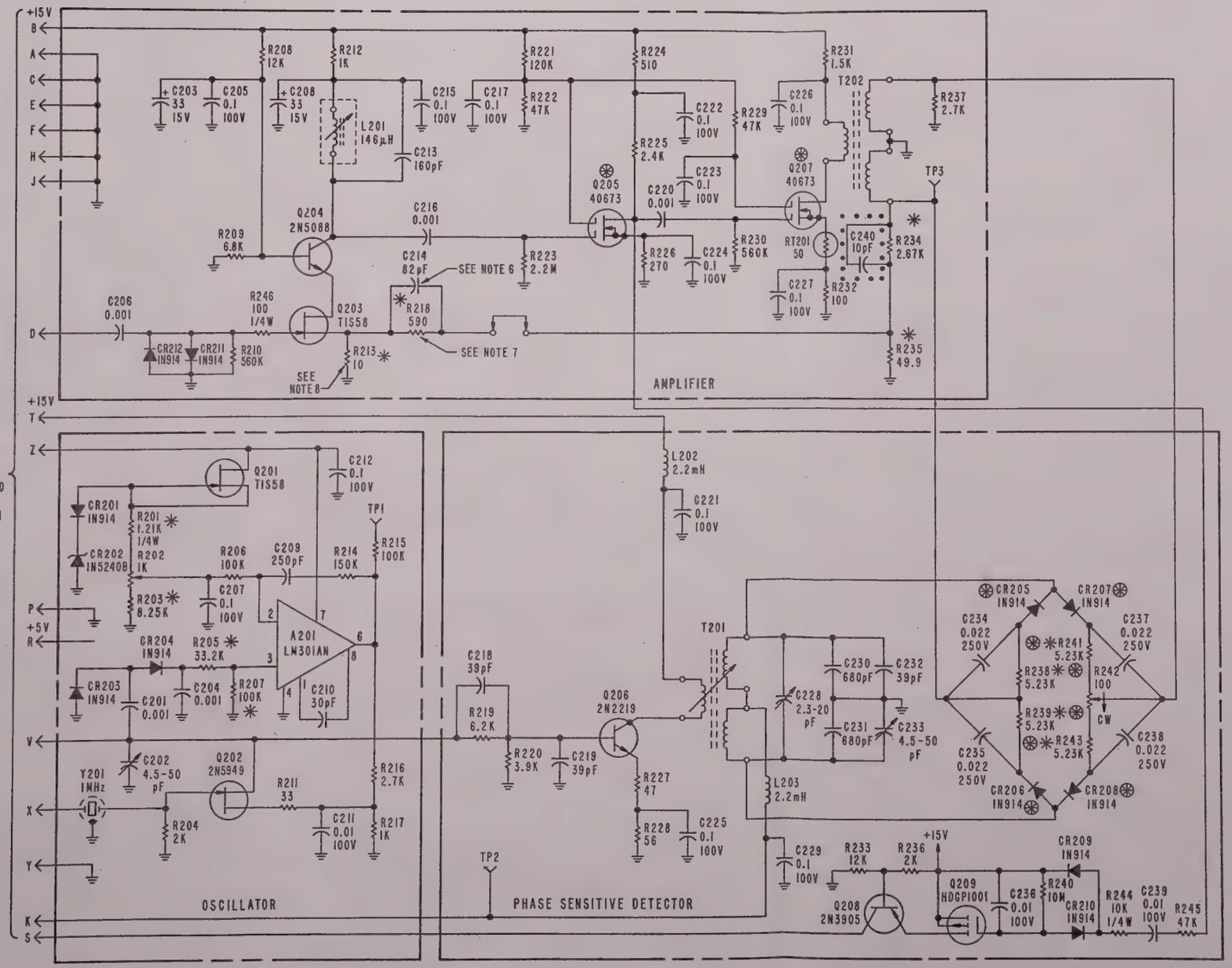
Reference	Description		BEC Part No.
	MASTER PC BOARD (CONTINUED)		
R8	Resistor, MF	1.62 kΩ 1%	341320
R9	Resistor, Var.	200 Ω 10% 1/2 W	311304
R10	Resistor, MF	604 Ω 1% 1/4 W	341275
R11	Resistor, MF	1.62 kΩ 1%	341320
R12	Resistor, Var.	200 Ω 10% 1/2 W	311304
R13	Resistor, MF	604 Ω 1% 1/4 W	341275
R14	Resistor, Comp.	510 Ω 5% 1/2 W	301080
R15	Resistor, Comp.	3.9 kΩ 5% 1/4 W	300096
R16	Resistor, Comp.	3.9 kΩ 5% 1/4 W	300096
R17 through R21	Resistor, Comp.	5.1 kΩ 5% 1/4 W	300099
R22	Resistor, Comp.	3.9 kΩ 5% 1/4 W	300096
R23	Resistor, Comp.	5.1 kΩ 5% 1/4 W	300099
R24	Resistor, Comp.	5.1 kΩ 5% 1/4 W	300099
R25	Resistor, Comp.	5.1 kΩ 5% 1/4 W	300099
R26	Resistor, MF	10 kΩ 1% 1/4 W	341400
R27	Resistor, Var.	20 kΩ 10% 1 W	311266
R28	Resistor, Comp.	4.7 MΩ 5% 1/2 W	301175
R29	Resistor, Comp.	10 kΩ 5% 1/2 W	301111
R30	Resistor, Comp.	10 MΩ 5% 1/2 W	301183
R31		Not Used	
R32	Resistor, MF	63.4 kΩ 1% 1/4 W	341477
R33	Resistor, MF	10 kΩ 1% 1/4 W	341400
R34	Resistor, Comp.	1.3 kΩ 5% 1/2 W	301090
R35	Resistor, MF	3.65 kΩ 1% 1/4 W	341354
R36	Resistor, MF	26.1 kΩ 1% 1/4 W	341440
R37	Resistor, Var.	5 kΩ 10% 1 W	311268
R38	Resistor, Var.	200 Ω 10% 1 W	311269
R39	Resistor, MF	1.21 kΩ 1% 1/4 W	341308
R40	Resistor, MF	54.9 kΩ 1% 1/4 W	341471
R41	Resistor, Var.	5 kΩ 10% 1 W	311268
R42	Resistor, Comp.	4.7 kΩ 5% 1/2 W	301103
R43	Resistor, Comp.	330 Ω 5% 1/4 W	300070
T2	Osc. Transformer Assembly		062005-1
	OSCILLATOR/AMPLIFIER BOARD		
A201	Amp.	LM301AN	535012
C201	Capacitor, Cer.	0.001 µF 500 V	224114
C202	Capacitor, Cer. Var.	4.5 - 50 pF (Green)	281006
C203	Capacitor, Elec.	33 µF 20% 15 V	283206
C204	Capacitor, Cer.	0.001 µF 500 V	224114
C205	Capacitor, PE	0.1 µF 10% 100 V	234080
C206	Capacitor, Cer.	0.001 µF 500 V	224114
C207	Capacitor, PE	0.1 µF 10% 100 V	234080
C208	Capacitor, Elec.	33 µF 20% 15 V	283206

Reference	Description		BEC Part No.
	OSCILLATOR/AMPLIFIER BOARD (CONTINUED)		
C209	Capacitor, Mica	250 pF 5% 500 V	200036
C210	Capacitor, Mica	30 pF 5% 500 V	200073
C211	Capacitor, Cer.	0.01 µF 100 V	224119
C212	Capacitor, PE	0.1 µF 10% 100 V	234080
C213	Capacitor, Mica	160 pF 5% 500 V	200048
C214	Capacitor, Mica	430 pF 1% 500 V	200037
C215	Capacitor, PE	0.1 µF 10% 100 V	234080
C216	Capacitor, Cer.	0.001 µF 500 V	224114
C217	Capacitor, PE	0.1 µF 10% 100 V	234080
C218	Capacitor, Mica	39 pF 5% 500 V	200025
C219	Capacitor, Mica	39 pF 5% 500 V	200025
C220	Capacitor, Cer.	0.001 µF 500 V	224114
C221 through C227	Capacitor, PE	0.1 µF 10% 100 V	234080
C228	Capacitor, Cer. Var.	2.3 - 20 pF (Blue)	281005
C229	Capacitor, PE	0.1 µF 10% 100 V	234080
C230	Capacitor, Mica	680 pF 1% 300 V	200015
C231	Capacitor, Mica	680 pF 1% 300 V	200015
C232	Capacitor, Mica	39 pF 5% 500 V	200025
C233	Capacitor, Cer. Var.	4.5 - 50 pF (Green)	281006
C234	Capacitor, PE	0.022 µF 20% 250 V	234079
C235	Capacitor, PE	0.022 µF 20% 250 V	234079
C236	Capacitor, Cer.	0.01 µF 100 V	224119
C237	Capacitor, PE	0.022 µF 20% 250 V	234079
C238	Capacitor, PE	0.022 µF 20% 250 V	234079
C239	Capacitor, Cer.	0.01 µF 100 V	224119
C240	Capacitor, Mica	10 pF 5% 500 V	200022
CR201	Diode, Sig.	1N914	530058
CR202	Diode, Zen.	1N5240B	530077
CR203	Diode, Sig.	1N914	530058
CR204	Diode, Sig.	1N914	530058
CR205 through CR208	Diode	Sel.	530131
CR209	Diode, Sig.	1N914	530058
CR210	Diode, Sig.	1N914	530058
CR211	Diode, Sig.	1N914	530058
CR212	Diode, Sig.	1N914	530058
L201	Inductor, Var. Unit		400275
L202	Choke	2.2 mH	400141
L203	Choke	2.2 mH	400141
Q201	Transistor	TIS58	528038
Q202	Transistor	2N5459 (Sel.)	528095
Q203	Transistor	TIS58	528038
Q204	Transistor	2N5088	528047

Reference		Description	BEC Part No.
		OSCILLATOR/AMPLIFIER BOARD (CONTINUED)	
Q205	Transistor	40673 (Sel.)	528090
Q206	Transistor	2N2219	528014
Q207	Transistor	40673 (Sel.)	528090
Q208	Transistor	2N3905	528025
Q209	Transistor	HDGP-1001	528057
R201	Resistor, MF	1.21 kΩ 1% 1/4 W	341308
R202	Resistor, Var.	1 kΩ 10% 3/4 W	311226
R203	Resistor, MF	8.25 kΩ 1% 1/4 W	341388
R204	Resistor, Comp.	2 kΩ 5% 1/2 W	301094
R205	Resistor, MF	33.2 kΩ 1% 1/4 W	341450
R206	Resistor, Comp.	100 kΩ 5% 1/2 W	301135
R207	Resistor, MF	100 kΩ 1% 1/4 W	341500
R208	Resistor, Comp.	12 kΩ 5% 1/2 W	301113
R209	Resistor, Comp.	6.8 kΩ 5% 1/2 W	301107
R210	Resistor, Comp.	560 kΩ 5% 1/2 W	301153
R211	Resistor, Comp.	33 Ω 5% 1/2 W	301051
R212	Resistor, Comp.	1 kΩ 5% 1/2 W	301087
R213	Resistor, MF	13 Ω 1% 1/4 W	341111
R214	Resistor, Comp.	150 kΩ 5% 1/2 W	301139
R215	Resistor, Comp.	100 kΩ 5% 1/2 W	301135
R216	Resistor, Comp.	2.7 kΩ 5% 1/2 W	301097
R217*	Resistor, Comp.	820 Ω 5% 1/2 W	301085
R217*	Resistor, Comp.	1 kΩ 5% 1/2 W	301087
*One of the above resistors to be selected during calibration			
R218	Resistor, MF	60.4 Ω 1% 1/4 W	341175
R219	Resistor, Comp.	6.2 kΩ 5% 1/2 W	301106
R220	Resistor, Comp.	3.9 kΩ 5% 1/2 W	301101
R221	Resistor, Comp.	120 kΩ 5% 1/2 W	301137
R222	Resistor, Comp.	47 kΩ 5% 1/2 W	301127
R223	Resistor, Comp.	2.2 MΩ 5% 1/2 W	301167
R224	Resistor, Comp.	510 Ω 5% 1/2 W	301080
R225	Resistor, Comp.	2.4 kΩ 5% 1/2 W	301096
R226	Resistor, Comp.	270 Ω 5% 1/2 W	301073
R227	Resistor, Comp.	47 Ω 5% 1/2 W	301055
R228	Resistor, Comp.	56 Ω 5% 1/2 W	301057
R229	Resistor, Comp.	47 kΩ 5% 1/2 W	301127
R230	Resistor, Comp.	560 kΩ 5% 1/2 W	301153
R231	Resistor, Comp.	1.5 kΩ 5% 1/2 W	301091
R232	Resistor, Comp.	100 Ω 5% 1/2 W	301063
R233	Resistor, Comp.	12 kΩ 5% 1/2 W	301113
R234	Resistor, MF	2.67 kΩ 1% 1/4 W	341341
R235	Resistor, MF	49.9 Ω 1% 1/4 W	341167
R236	Resistor, Comp.	2 kΩ 5% 1/2 W	301094
R237	Resistor, Comp.	2.7 kΩ 5% 1/2 W	301097
R238	Resistor, MF	Sel.	325399
R239	Resistor, MF	Sel.	325399

Reference	Description		BEC Part No.
	OSCILLATOR/AMPLIFIER BOARD (CONTINUED)		
R240	Resistor, Comp.	10 MΩ 5% 1/2 W	301183
R241	Resistor, MF		325399
R242	Resistor, Var.	100 Ω 10% 1 W	311338
R243	Resistor, MF		325399
R244	Resistor, Comp.	10 kΩ 5% 1/4 W	300106
R245	Resistor, Comp.	47 kΩ 5% 1/2 W	301127
RT201	Thermistor	50 Ω 10%	325011
T201	Phase Sens. Det. Transformer Unit		400235
T202	Amp. Output Transformer Unit		400265
Y201	Crystal	1 MHz	547020





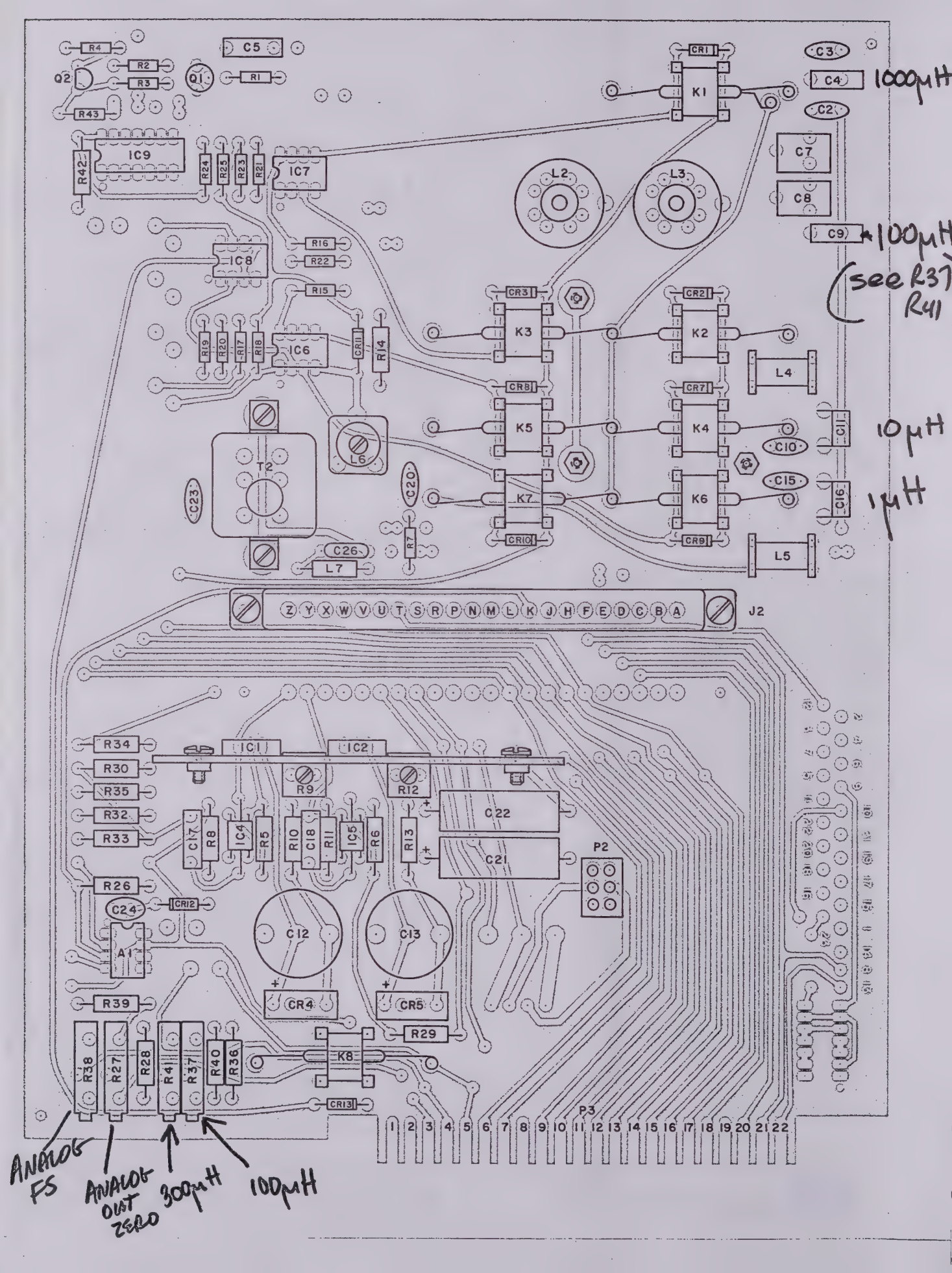
NOTES:

1. CAPACITANCE VALUES IN µF, UNLESS OTHERWISE SPECIFIED.
2. RESISTANCE VALUES IN OHMS & 1/2 WATT, UNLESS OTHERWISE SPECIFIED.
3. ✳ PRECISION RESISTORS, 3/8 WATT.
4. ⊛ FACTORY SELECTED.
5. LAST NUMBERS USED: R246 C240 CR212 Q209
6. ON 72B-03 THIS VALUE IS 430pF.
7. ON 72B-03 THIS VALUE IS 60.4 .
8. ON 72B-03 THIS VALUE IS 13 .
9. ▪ ▪ ▪ ▪ SIGNIFIES COMPONENT ADDED FOR 72B-03.
10. NOTES 6, 7, 8 AND 9 ALSO APPLY TO 62A AND 62AD.

COMPONENT NUMBERS
200 SERIES

BOONTON ELECTRONICS CORPORATION

72B,B-03,B-S1-03,72BD,62A,62AD
Schematic, Osc./Amp.
D830651K, Sheet 2 of 3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R2
R3
R43
Q2
Q1
C5
R1
IC9
R42
R24
R25
R23
R21
IC7
IC8
R16
R22
R15
R19
R20
R17
R18
IC6
CR11
R14
T2
L6
C23
C20
R7
C26
L7
CR1
K1
C3
C4
1000µH
C2
C7
C8
L2
L3
C9
100µH
(see R37
R41)
CR3
K3
CR2
K2
L4
CR8
K5
CR7
K4
C10
C11
10µH
C15
K7
K6
C16
1µH
CR10
CR9
L5
Z Y X W V U T S R P N M L K J H F E D C B A
J2
R34
R30
R35
R32
R33
IC1
IC2
R9
R12
C17
R8
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R5
R10
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R13
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A1
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C13
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R27
R28
R41
R37
R40
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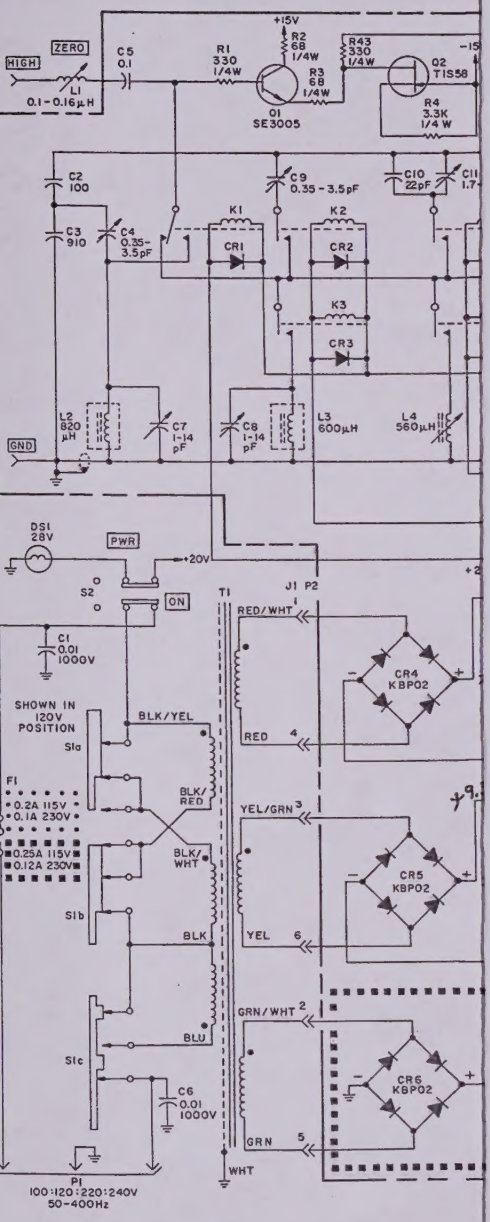
ANALOG FS
ANALOG OUT ZERO
300µH
100µH



NOTES:

1. CAPACITANCE VALUES IN µF, UNLESS OTHERWISE SPECIFIED.
2. RESISTANCE VALUES IN OHMS & 1/2W UNLESS OTHERWISE SPECIF
3. DIODES ARE TYPE IN914, UNLESS OTHERWISE SPECIFIED.
4. * PRECISION RESISTORS, 3/8 WATTS.
5. ▭ EXTERNAL MARKINGS.
6. ▪▪▪ COMPONENTS USED ON 62A, ONLY.
7. ▪▪▪ COMPONENTS USED ON 62AD, ONLY.
8. LAST NUMBERS USED:
   R43, C26, CR14, IC10

BOONTON ELECTRONICS CORPORATION

MODEL 62A, 62AD
Schematic, Master Bd. (A1)
E830763C

MP MASTER
MA24720